Advanced Gas/Gas Injector Technology

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To provide a rocket engine injector technology base for supporting the Reusable Launch Vehicle (RLV) engine development, a study of high-performance injectors associated with various engine cycles has been performed by MSFC and Pennsylvania State University (PSU) under the NASA Research Announcement (NRA) Cooperative Agreement NCC8–46. The recent effort in this activity focused on the advanced gas/gas injector. Based on the results of previous investigations on other injector types, it was suggested that a swirl coaxial injector may provide effective propellant mixing; hence it was selected for this study. Three variations of the swirl coaxial injector, having oxidizer swirl angles of 60, 75, and 95 degrees, were fabricated and tested in a hot-fire environment. Detailed dimensions of the three injectors are summarized in table 1. The injectors were designed for a gaseous oxygen/hydrogen propellant system at an oxidizer/fuel mixture ratio (MR) of six with the chamber pressure of 1,000 psia. The purpose of the experiments is to evaluate the mixing/combustion processes and the injector face heat transfer characteristics.

The experiments were conducted with a 2- by 2-in square uni-element combustor equipped with helium-cooled windows. The windows allow optical access into the combustion chamber for laser-based diagnostic techniques. Raman spectroscopy was used to measure the major species at 3.5 in downstream of the injector face. The species Raman signals were calibrated and presented in terms of the species mole fraction, as shown in figure 20, for the test results of the 60-degree swirl-angle injector. The measured data indicate uniform distribution of species in the radial direction, which suggests that the gaseous propellants were well-mixed and combusted at this axial location. The other two derivative injectors also behaved in a similar manner.

Injector face temperature was measured with the aid of a type “K” thermocouple silver brazed at a location 0.425-in from the injector center line. The temperature measurements, sampled at 200 Hz for the 2-sec duration rocket firings, as plotted in figure 21, show that the injector face temperature is lowest for the 60-degree oxidizer swirl angle injector and nominally the same for the 75-degree and 90-degree swirl injectors. The high temperatures indicate that the energy release for the swirl coaxial injector is close to the face, and hence, the possible use of this type of injector for actual rocket engines will require face-cooling schemes.

In conclusion, the results of this investigation suggest that the generic swirl injector for a gas/gas propellant system will have efficient propellant mixing/combustion characteristics. However, actual implementation of this type of injector will require a tradeoff between injector face temperature

Table 1.—*Swirl coaxial injector dimensions.*

	GO_2 Post Diameter (d_o)	GH_2 Annulus Inner Diameter (d_{Fi})	GH_2 Annulus Outer Diameter (d_{Fo})
60° Swirl	0.210 in (5.33 mm)	0.250 in (6.35 mm)	0.290 in (7.37 mm)
75° Swirl	0.277 in (7.04 mm)	0.317 in (8.05 mm)	0.357 in (9.07 mm)
90° Swirl	0.370 in (9.40 mm)	0.410 in (10.4 mm)	0.450 in (11.4 mm)

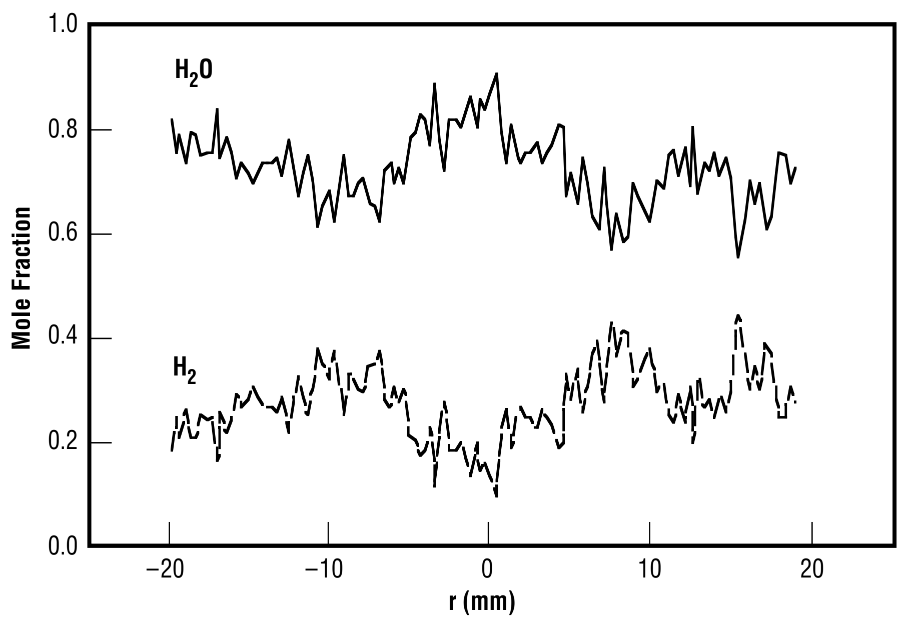

Figure 20.—Average GH_2 and H_2O mole fraction for a 60° swirl inject or at pc = 993 psia.

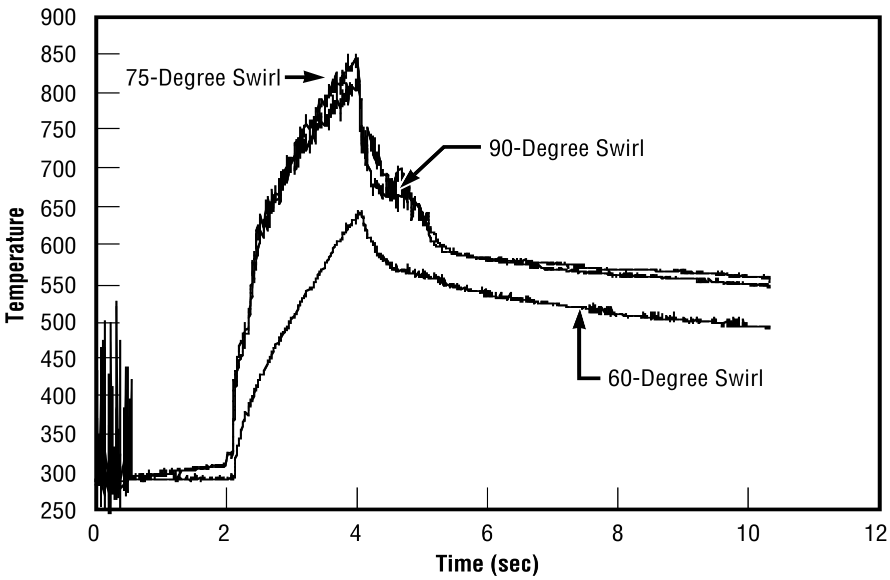

Figure 21.—Injector face temperature for the three coaxial injectors having 60-, 75-, and 90-degree swirl angles.

requirements and mixing/combustion efficiency.

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University/Industry Involvement: Robert J. Santoro and Charles Merkle, The Propulsion Engineering Research Center of the Pennsylvania State University.

Biographical Sketch: Huu P. Trinh has worked in the area of liquid rocket engine combustion at MSFC since 1987. He has used computational and analytical models to analyze rocket engine performances. Currently, he monitors a project of providing technologies for main chamber and preburner injectors. The effort is conducted under a PSU NRA cooperative agreement to support the RLV program. In addition, he evaluates injector performance of the Fastrac engine and analyzes proposed Bantam main and gas generator injectors.